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Design Charts for Spacing of Vacuum Line Supports*

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DESIGN CHARTS FOR SPACING OF VACUUM LINE SUPPORTS

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Introduction

This paper presents design tables and graphs to aid engineers and designers in the selection of support spacing for vacuum beam lines and other vacuum pipes. This data applies to support spacing for thin wall pipes and tubes under a internal vacuum (or open to atmosphere) and subject to external atmospheric pressure. Data is generated from the equations for a simply supported thin walled pipe or tube of circular cross section.[1]

These tables and graphs indicate what the minimum spacing of supports is for a pipe or tube of a given radius and supply data for carbon steel, stainless steel, aluminum and copper materials. The wall thickness of the pipe and tube is limited to 1/10 of the pipe radius ($T \ll R/10$). A thickness of R/10 results in a decrease in the length values in the attached tables of 10%, whereas a thickness of R/100 results in a decrease in the length values in the attached tables of 1%.

Snow loads, wind loads, equipment loads, etc. are not included in the tables and graphs. This data is applicable for vacuum pipes or tubes under its own static dead weight.

Criteria Used For Tables And Graphs

The basic loadings to be considered in the selection of support spacing for vacuum system pipe or tube runs is the weight of the pipe or tube (not including the weight of the fittings and valves) and what deflection or stress is acceptable. The moments and reactions caused by these loads can be computed by the law of statics. The spacing of supports is governed by: 1) The acceptable deflection of the pipe and 2) The allowable stress in the pipe.

The worst case is a simply supported beam uniformly loaded. The static equations that govern the problem are:[2]

$$M = \frac{WL^2}{8} \qquad Y = \frac{5\,WL^4}{384\,EI} \qquad S = \frac{MC}{I}$$

Where M = Bending Moment
L = Length of Pipe
W = Uniform Load in LBS/IN
E = Modulus of Elasticity
I = Moment of Inertia
S = Bending Stress
C = R Where R = Radius of Pipe

It can also be shown for a thin walled pipe:[3]

$$A = 2\pi RT \qquad I = \pi R^3 T$$

Where
A = Area of Pipe
R = Radius of Pipe
T = Wall Thickness of Pipe
I = Moment of Inertia
π = 3.141593

Then

$$W = \frac{VP}{L} = \frac{2\pi RTLP}{L} = 2\pi RTP$$

Where
P = Density of Pipe
V = Volume of Pipe Material

Combining the Above Equations for Deflection:

$$Y = \frac{5\,WL^4}{384\,EI} = \frac{5 \times 2 \times \pi RTPL^4}{384\,\pi ETR^3} = \frac{5\,PL^4}{192\,ER^2}$$

Rearranging and Solving for Length:

$$L = \left(\frac{192\,YER^2}{5\,P}\right)^{1/4} \qquad \text{(Equation 1)}$$

Combining the Above Equations for Stress:

$$S = \frac{WCL^2}{8\,I} = \frac{2\pi RTPL^2}{8\,\pi TR^2} = \frac{PL^2}{4\,R}$$

Rearranging and Solving for Length:

$$L = \left(\frac{4\,SR}{P}\right)^{1/2} \qquad \text{(Equation 2)}$$

Using a computer program the attached Tables and Graphs were generated for the following materials:

A. Carbon / Stainless Steel (Table 1 and Graph 1)
S = 18,750 PSI; E = 30,000,000 PSI; P = .284 PCI

B. Copper (Table 2 and Graph 2)
S = 6,700 PSI; E = 17,000,000 PSI; P = .322 PCI

C. Aluminum (Table 3 and Graph 3)
S = 10,000 PSI; E = 10,000,000 PSI; P = .100 PCI

Precautions

The following precautions should be observed:

1. Tables and Graphs only apply for material that has a minimum physical property better than those shown above.
2. The pipe is carrying no internal fluid.
3. The pipe has no external load other than its own static dead weight and is not subject to any dynamic load.
4. The pipe is not subject to any wind, ice or snow loads.
5. No provisions were included for fittings or valves that may cause higher loadings on the pipe.
6. These Tables and Graphs are for pipes and tubes that are under vacuum (or open to atmosphere) and subject to external atmospheric pressure.
7. Thickness is limited to 1/10 of the radius ($T \ll R/10$).

Intended Use Of Tables And Graphs

These tables and graphs are intended to give deflection and stress information for simply supported lengths of round pipe and tubes under self weight static condition only.

This data is not intended for pipes and tubes under maximum stress or deflection condition. Extremely long pipes and tubes should be analyzed in more detail.

Bibliography

[1]American Institute of Steel Construction, Manual of Steel Construction, Eighth Edition. p. 2-114

[2]American Institute of Steel Construction, Manual of Steel Construction, Eighth Edition. p. 2-114

[3]Roark, Raymond J. and Young, Warren C., Formulas for Stress and Strain, Fifth Edition, p. 66

Acknowledgements

We wish to acknowledge the efforts made by Julie Heim and John Rauch in the preparation of these tables and graphs.

TABLE NO. 1
MAXIMUM UNSUPPORTED LENGTH FOR CARBON STEEL & STAINLESS STEEL

PIPE OR TUBE RADIUS (INCHES)	MAXIMUM UNSUPPORTED LENGTH OF PIPE (FEET) FOR ACCEPTABLE DEFLECTION (Δ) OR ALLOWABLE STRESS (σ)									
	Δ = 1/16"	Δ = 1/8"	Δ = 1/4"	Δ = 1/2"	Δ = 1"	Δ = 2"	Δ = 5"	Δ = 10"	Δ = 15"	σ = 18750 psi
1/2	7	9	11	13	15	18	22	26	29	30
1	11	13	15	18	21	25	31	37	41	43
2	15	18	21	25	30	35	44	53	59	61
3	18	22	26	31	36	43	54	65	72	74
4	21	25	30	35	42	50	63	75	83	86
5	24	28	33	40	47	56	70	84	92	96
6	26	31	36	43	52	61	77	92	101	105
7	28	33	39	47	56	66	83	99	110	113
8	30	35	42	50	60	71	89	106	117	121
9	32	38	45	53	63	75	94	112	124	129
10	33	40	47	56	67	79	99	118	130	136
11	35	41	49	59	70	83	104	124	137	142
12	36	43	52	61	73	87	109	130	143	148

TABLE NO. 2
MAXIMUM UNSUPPORTED LENGTH
FOR COPPER

PIPE OR TUBE RADIUS (INCHES)	MAXIMUM UNSUPPORTED LENGTH OF PIPE (FEET) FOR ACCEPTABLE DEFLECTION (Δ) OR ALLOWABLE STRESS (σ)						
	Δ = 1/16"	Δ = 1/8"	Δ = 1/4"	Δ = 1/2"	Δ = 1"	Δ = 2"	σ = 6700 psi
1/2	6	7	9	11	13	15	17
1	9	11	13	15	18	21	24
2	13	15	18	21	25	30	34
3	15	18	22	26	31	36	42
4	18	21	25	30	35	42	48
5	20	24	28	33	40	47	54
6	22	26	31	36	43	52	59
7	23	28	33	39	47	56	64
8	25	30	35	42	50	59	68
9	27	32	38	45	53	63	72
10	28	33	40	47	56	67	76
11	29	35	41	49	59	70	80
12	31	36	43	52	61	73	83

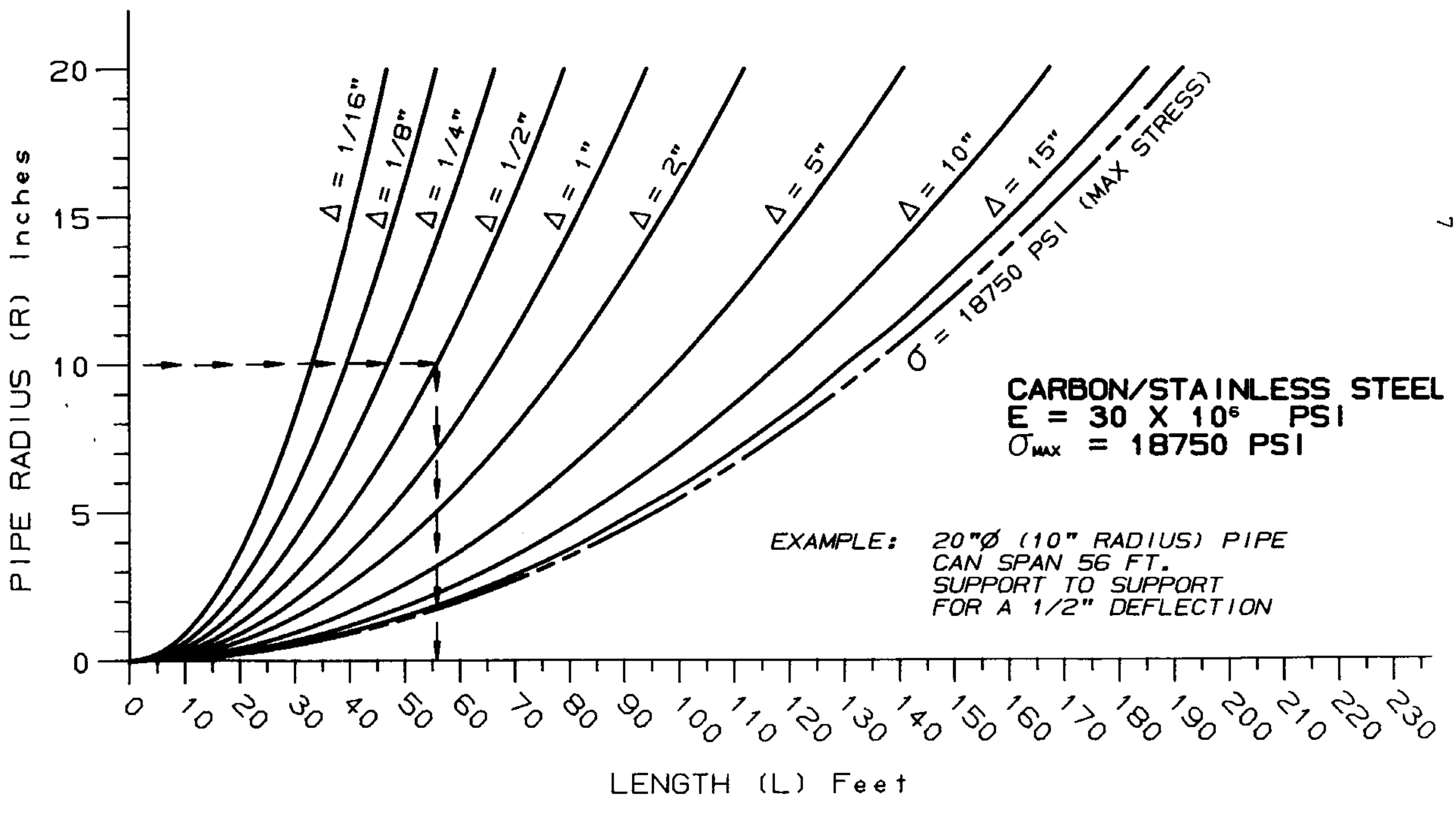
TABLE NO. 3
MAXIMUM UNSUPPORTED LENGTH
FOR ALUMINUM

PIPE OR TUBE RADIUS (INCHES)	MAXIMUM UNSUPPORTEDED LENGTH OF PIPE (FEET) FOR ACCEPTABLE DEFLECTION (Δ) OR ALLOWABLE STRESS (σ)									
	Δ = 1/16"	Δ = 1/8"	Δ = 1/4"	Δ = 1/2"	Δ = 1"	Δ = 2"	Δ = 5"	Δ = 10"	Δ = 15"	σ = 10000 psi
1/2	7	9	10	12	15	17	22	26	29	37
1	10	12	15	17	21	25	31	37	41	53
2	15	17	21	25	29	35	44	52	58	75
3	18	21	25	30	36	43	54	64	71	91
4	21	25	29	35	41	49	62	74	82	105
5	23	28	33	39	46	55	69	82	91	118
6	25	30	36	43	51	60	76	90	100	129
7	27	33	39	46	55	65	82	98	108	139
8	29	35	41	49	59	70	88	104	115	149
9	31	37	44	52	62	74	93	111	122	158
10	33	39	46	55	66	78	98	117	129	167
11	34	41	49	58	69	82	103	122	135	175
12	36	43	51	60	72	85	107	128	141	183

GRAPH NO. 1

CARBON/STAINLESS STEEL

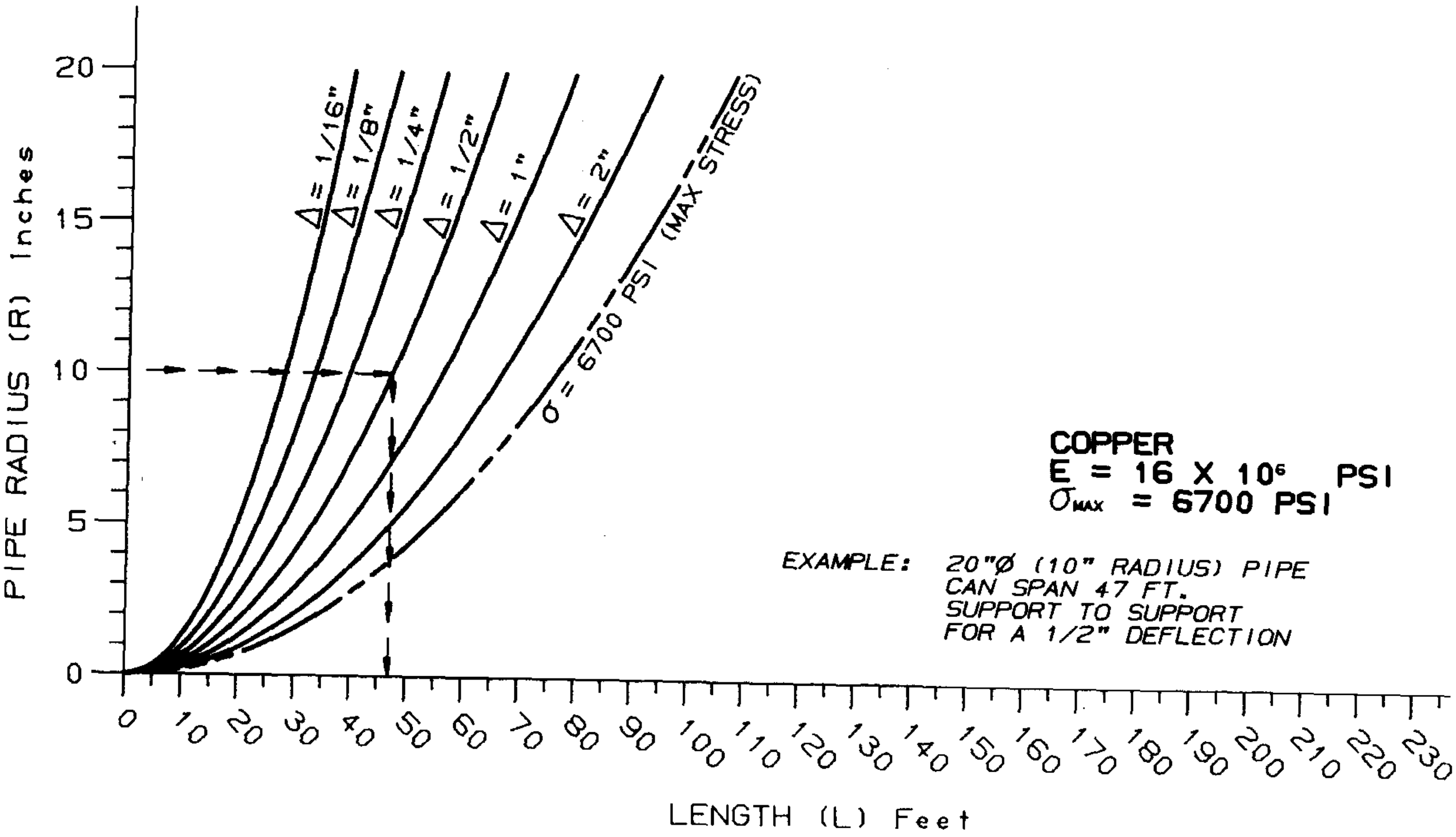
UNSUPPORTED LENGTH OF VACUUM PIPES



GRAPH NO. 2

COPPER

UNSUPPORTED LENGTH OF VACUUM PIPES



GRAPH NO. 3

ALUMINUM
UNSUPPORTED LENGTH OF VACUUM PIPES